
Space Weather Technical Forecast

Issued on Friday, 01 December 2023 at 01:13 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales <https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales>

Space Weather Forecast Headline: Chance of M-class flares (R1-R2 Blackouts). G1-G2 Minor to Moderate storms expected, with a chance of G3 Strong storms from multiple CME arrivals today.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Low, with a peak flare of C3.6 at 30/2248 UTC from a region just behind the southwest limb. There are currently eleven sunspot regions with AR3500 the largest and previously the most active. The region is currently comprised of a cluster of spots with small umbrae and is currently classified as Eac/beta-gamma, although at one point during the previous 24 hours a weak delta spot was close to developing. All other regions on the disc remain smaller and simpler, and generally either stable or showing signs of decay. However, AR3052 produced the second largest flare of the 24 hour period, a long duration C2.9 flare, and therefore became the most active on the Earth facing side of the Sun. There are also a number of filaments on the Earth-facing disc.

No Earth-directed CMEs occurred during this period, however there are a number of other potentially Earthbound CMEs in the forecast from previous days.

Solar Wind / Geomagnetic Activity: Solar wind speeds, as observed by ACE at L1, were at Background levels between 350-400 km/s until 30/2328 UTC when the speed jumped to 450 km/s. Density remained below average. Interplanetary Magnetic Field (IMF), Bt, was weak until 30/2328 UTC when the Bt jumped to 10 nT. At the same time the north-south component, Bz, dropped to -7 nT having previously weakly fluctuated. Phi angle was positive (away from the Sun). These solar wind parameter indicate the arrival of a weak CME, most likely from a filament eruption late on the 27th. Geomagnetic activity was Quiet (Kp 0-2).

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux remained at background. GOES16 high energy (greater than 2MeV) electron flux varied between Background and moderate, peaking at 394 pfu at 30/1915 UTC. The associated 24-hour fluence has remained below the Active threshold (1e8 integrated pfu) with a steady trend. The observation at 01/0000 UTC was 1.39e7 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Low to Moderate with a chance of isolated M-flares (R1-R2 Blackout), and a slight chance of an isolated X-class flare (R3 Blackout). AR3500 is most likely to be the source of any significant flares.

Solar Wind / Geomagnetic Activity: There are two further Earth-directed CMEs expected; one originates from a filament eruption during the morning of the 28th and the other, a more significant CME, from the M9.8 flare from AR3500 on later on the 28th Nov.

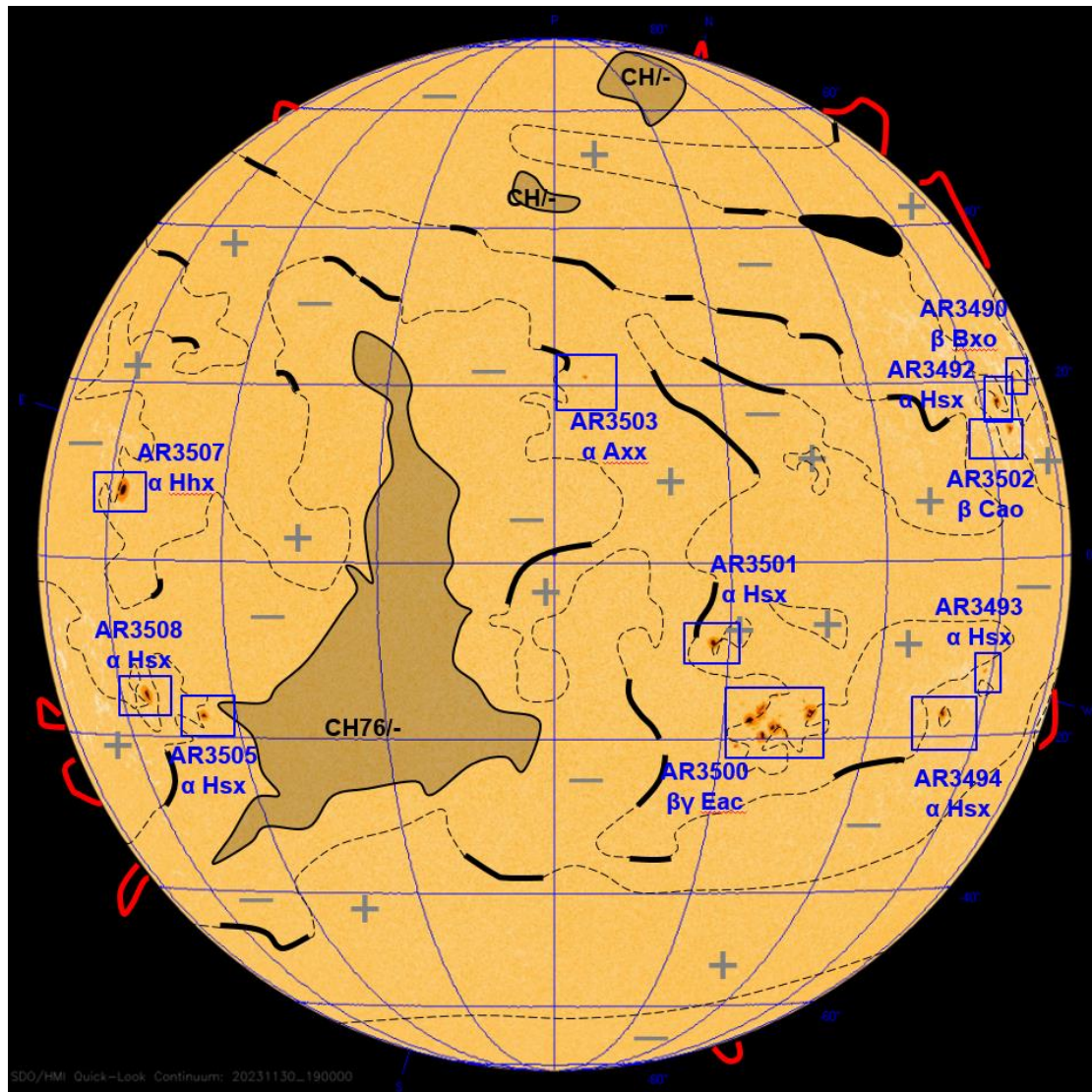
Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

The M9.8 sourced CME is forecast to arrive today (1st) around 1100 UTC, although the speed of this CME is low confidence. This CME is also likely to sweep up and cannibalise the other CME, which was forecast to arrive later today, potentially enhancing the impact when this occurs. Aside from the CME's current Slightly Elevated to Background winds are forecast to continue, until late in the period when a High Speed Stream (HSS) from CH76 is due to arrive, bringing Elevated winds of around 500-550 km/s.

Geomagnetic activity is initially expected to be Active to G1/Minor Storm (Kp 4-5) due to the weak arrival of the CME from the 27th. The CME arrivals are then likely to bring spells of G1/Minor or G2/Moderate geomagnetic storms today and tomorrow (1st and 2nd Dec) with a chance of G3/Strong storms. Geomagnetic activity then gradually eases to Quiet to Unsettled levels (Kp 2-3) for day 3 and part of day 4 (3rd and 4th Dec). Late day 4 activity is expected to increase Active to G1/Minor Storm (Kp 4-5) due to the arrival of the HSS.

Energetic Particles / Solar Radiation: GOES16 high energy proton flux is expected to remain at background levels. However, any significant flares, mainly from AR3500, or any notable filament eruptions will bring a chance of flux levels increasing, with a slight chance of approaching or perhaps exceeding the S1 Minor Radiation Storm level. Electron flux is forecast to be Moderate levels initially but then quickly falling to Background levels today, due to the recent CME arrival. Some recovery of flux to Moderate, perhaps High at diurnal peak, is likely during day 3 (3rd), only to decrease to Background levels again as geomagnetic activity increases late day 4. The associated 24 hour fluence is forecast to remain below Active (1e8 integrated pfu), despite a rising trend later in the period.

Figure 1. Solar Analysis Valid 30/1900 UTC.



Key: Filament — , Prominence — , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

Geomagnetic Storms:

Solar wind parameter indicated the recent arrival of a weak CME, most likely from a filament eruption late on the 27th.

There are two further Earth-directed CMEs expected; one originates from a filament eruption during the morning of the 28th and the other, a more significant CME, from the M9.8 flare from AR3500 on later on the 28th Nov. The M9.8 sourced CME is forecast to arrive today (1st) around 1100 UTC, although the speed of this CME is low confidence. This CME is also likely to sweep up and cannibalise the other CME, which was forecast to arrive later today, potentially enhancing the impact when this occurs. Aside from the CME's current Slightly Elevated to Background winds are forecast to continue, until late in the period when a High Speed Stream (HSS) from CH76 is due to arrive. CH76 is a persistent feature, and is very similar in size and position to the previous rotation. In theory this would strengthen the use of persistence forecasting, but during the previous rotation a CME arrived, masking the influence of the coronal hole. Therefore the forecast Elevated winds, of around 500-550 km/s, have lower confidence than normal and faster winds may arrive.

Geomagnetic activity is initially expected to be Active to G1/Minor Storm (Kp 4-5) due to the weak arrival of the CME from the 27th. The CME arrivals are then likely to bring spells of G1/Minor or G2/Moderate geomagnetic storms today and tomorrow (1st and 2nd Dec) with a chance of G3/Strong storms. Geomagnetic activity then gradually eases to Quiet to Unsettled levels (Kp 2-3) for day 3 and part of day 4 (3rd and 4th Dec). Late day 4 activity is expected to increase Active to G1/Minor Storm (Kp 4-5) due to the arrival of the HSS.

Geo-Magnetic Storm	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Minor or Moderate	G1 to G2	No	80	60	10	50
Strong	G3	No	40	10	1	1
Severe	G4	No	5	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
28/0700	Partial	Filament and C6/7 flare	NE	380 km/s	01/1800 UTC	Likely to be swept up by CME below
29/0056	Full	M9.8 flare	S-centre disc	740 km/s	01/1100 UTC	Low confidence on speed and arrival time.

Figure 2: CME arrival late on the 30th, as shown by ACE. Most likely the CME from late on the 27th.

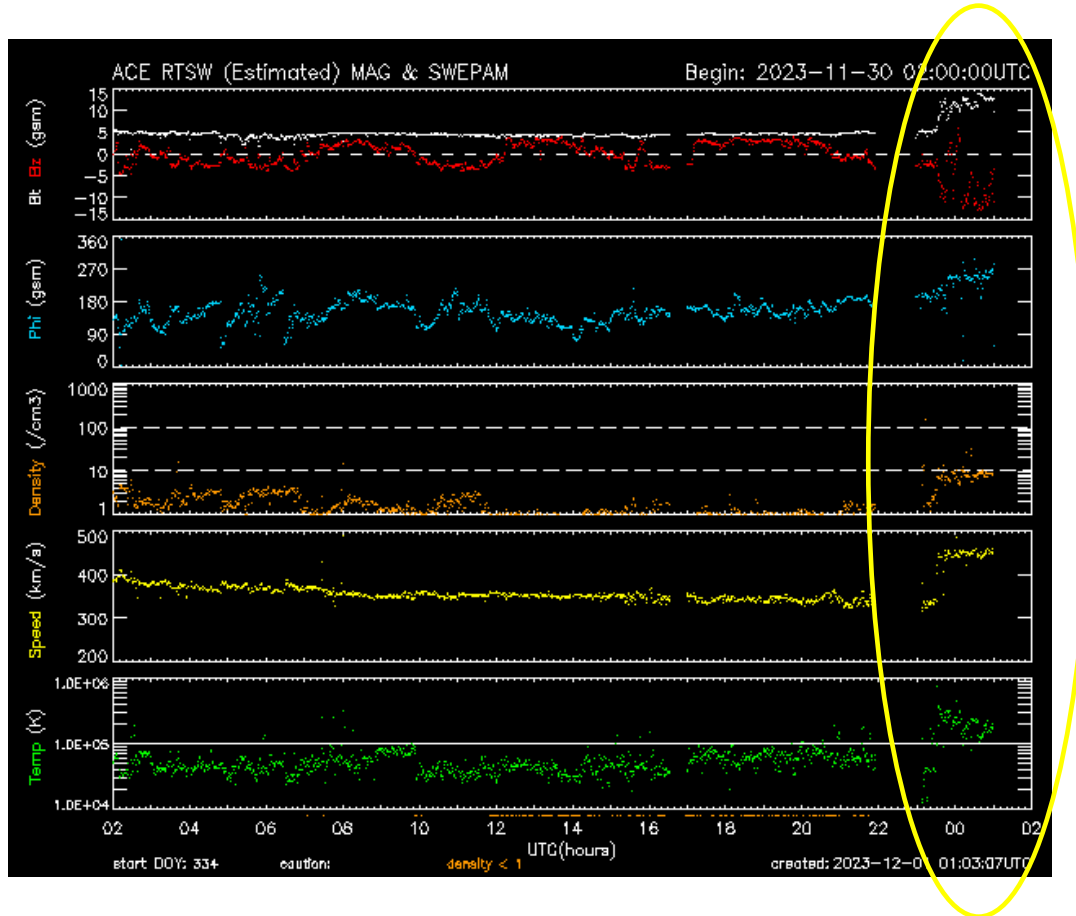
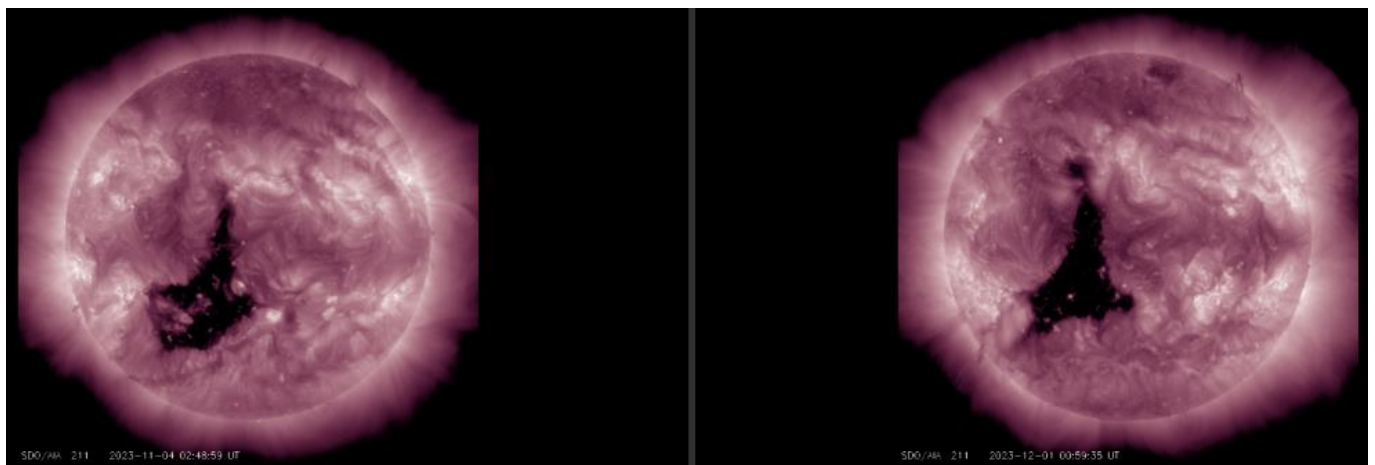


Figure 3: SDO AIA/211 images showing previous rotation (left) and current location of CH76 (right).



Radio Blackouts - X-Ray Flares:

There are eleven sunspots on the disc. AR3500 in the southwest remains the largest and most significant region. This is composed of a cluster of moderately sized, mixed polarity spots in the eastern part of the group and a more open leading western region. A small spot in its southern periphery has become separated from the previous penumbra, therefore the potential for a weak delta-spot development has reduced. Otherwise, despite the number of spots across the rest of the disc, they remain relatively small and simple, and predominantly mature and stable unipolar "H" spots. However, AR3502 has recently been re-classified as Cao/beta, with the penumbra of the main spot becoming asymmetric.

Solar activity is at Low levels with the largest flare of the previous 24 hours a C3.6 flare peaking at 30/2248 UTC, most likely from a region just behind the southeast limb. Low to Moderate activity is most probable, with an ongoing chance of isolated M-flares and a slight chance of an isolated X-class flare, primarily from AR3500.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	No	40	40	40	40
Very Active	R3 to R5 X Class	No	5	5	5	5

Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux observed by GOES16 is currently at background and expected to remain at this level. However, with the number of spots and filaments on the disc, there is a chance of flux increasing in response to any significant flares or eruptions. The main risk is from AR3500, in the southwest disc. This was the source of an M9.8 flare late on 28 Nov, and while no proton response was observed at Earth on this occasion, any subsequent flares will also have the potential to increase the observed proton flux.

Radiation Storms	Level (cm ⁻² sr ⁻¹ s ⁻¹)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ S1	No	10	10	10	10
Very Active	≥ S3 *	No	1	1	1	1

* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = cm⁻²sr⁻¹s⁻¹)

High Energy Electrons Event ($\geq 2\text{MeV}$):

Electron flux is forecast to be Moderate levels initially but then quickly falling to Background levels today, due to the recent CME arrival. Some recovery of flux to Moderate, perhaps High at diurnal peak, is likely during day 3 (3rd), only to decrease to Background levels again as geomagnetic activity increases late day 4.

The associated 24 hour electron fluence is expected to remain below the Active threshold ($1\text{e}8$ integrated pfu), as supported by REFM. However, a rising trend is likely from day 3 onward, once any CME influence recedes.

GEO Electron Environment	Level ($\text{cm}^{-2} \text{sr}^{-1} \text{day}^{-1}$)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	$\geq 2 \text{ MeV}$ $\geq 1 \times 10^8$	No	1	20	20	10
Very Active	$\geq 2 \text{ MeV}$ $\geq 1 \times 10^9$	No	1	1	1	1

Figure 4: MOSWOC REFM model.

